

METHOD FOR PRODUCING ANODE CAN FOR BATTERY AND  
MANGANESES DRY BATTERY USING SUCH ANODE CAN FOR BATTERY

Technical Field

[0001]

This invention relates to manufacture an anode zinc can for battery virtually not using and without adding lead to zinc for anode active material, and also relates to manufacture a manganese dry battery with such as can.

Background of the Invention

[0002]

Conventionally and currently general manufacturing method uses lead by adding it to zinc the main active material for battery anode for corrosion resistance against electrolyte. Especially in batteries with neutral to acid electrolyte such as manganese dry batteries 0.15 to 0.50 mass percent(%) of lead is added to anode zinc.

Further, addition of lead is for process ability of a zinc sheet. Anode zinc electrodes of cylindrical manganese dry batteries are generally made by extrusion molding of a zinc sheet of anode material in a heat from 100degrees Centigrade to 260degrees Centigrade, and an anode zinc plate for the laminated

dry battery 6F-22 is made by punching a thinly rolled zinc sheet into a designed shape. But pure zinc is a friable material, and a pure zinc sheet can not be extruded or punched to produce usable cans or plates. Therefore lead is added to help also process ability. But lead is one of environmental hazardous materials, so supply of anode zinc material without lead is now urgently needed and development of such materials is conducted enthusiastically.

[0003]

Impact extrusion or deep drawing of a rolled zinc sheet is a way to make an anode can with a bottom cover. Such processes are possible cause of electrolyte leakage when a battery is excessively discharged and a zinc can partly wears extraordinarily. How to solve this problem of electrolyte leakage is a crucial issue for quality improvement of manganese dry batteries. Another environmental crucial issue is scrapping batteries (lead therein) in or together with home wastes.

Realization of lead additive-free active material for a zinc battery anode is a paramount necessity of today.

[0004]

Technical development has been conducted for a long time to create active material for a zinc battery anode without adding lead and yet ensuring corrosion resistance and enough process ability. But so far none is successful to fulfill both requirements, and a battery lead additive-free is not available. Shortcomings

of the technical development are in corrosion resistance and in process ability.

For example, corrosion test; the method is to dip a sheet of an anode zinc sheet into battery electrolyte and measure decrease of the sheet weight on picking out of electrolyte for evaluation of material corrosion resistance. It is an adequate method for material evaluation, but wearing process of the anode zinc material by discharge reaction of a battery is not taken into account which is essential factor to consider practical use of a battery. And consideration lacks as to impurities by elution from cathodes material, a compound of manganese dioxide, electrolyte and conductive material. As for process ability development works did many about material hardness, deformation and dent after extrusion or deep drawing but the works have been unable to find a material fault causing microscopic defects.

[0005]

There is a development case presenting use of an alloy of zinc adding some or at least any one of indium, aluminum, and gallium instead of lead for a battery anode can. (Reference: JP6-196156A) This technology was developed focusing on crystal grain diameter and corrosion resistance of anode zinc material.

The technology enables to produce a same level of material as lead added zinc material by maximum addition of indium, in corrosion resistance as  $0.82 \text{ mg/ c m}^2$ . The test electrolyte contains inevitable impurities such as Ni, Co, and Cu. And, the

technology lacks anticipation of impurities which elute from the cathode compound material when a battery is stored for a long period or at the time of discharge halt in an intermittent discharging. Because of aforesaid flaw, it is difficult to deem the anode material by this technology useable enough for practically marketable batteries.

[0006]

Another known technology is a method to prevent corrosion of anode by adding bismuth to active material for zinc anode while limiting amount of nickel, cobalt, and copper to add to manganese dioxide, the active material for cathode. (Reference: JP7-45272A) A problem with this technology is inability of controlling cracks among material crystals entailed during process of anode zinc cans, being little study seems to have been made about microscopic structure of anode materials. So this method is not competent enough to ensure reliability of battery quality for a long time. By this method corrosion due to impurities eluted from the cathode compound material is deemed not to be sufficiently deterred from growing, so battery quality can not be stable. In applying this method, anticorrosion material was necessary to add to the anode zinc can material, for no consideration is given in the method as to reactive wearing process of a can to be caused by discharge reaction of a battery.

Disclosure of this Invention

[0007]

This invention offers a highly reliable active material for battery anode, battery anode cans, anode zinc sheets, and manganese dry batteries thereby.

(1) An example of implementing this invention presents (1) an active material for battery anode which consists of zinc for major ingredient and does not contain lead virtually. The material features low decrease of a can wall less than or equal to 3.8 mg after 10cm<sup>2</sup> piece of the sheet from a can is placed still in a vessel filled with electrolyte which concentration is nickel 2.9ppm, cobalt 0.40ppm, and copper 0.86ppm, and the vessel is placed in a constant temperature water chamber in 45degrees Centigrade for 66 hours; or

(2) To use more than or equal to 99.99% concentration of zinc, and apply a material which major ingredient is zinc with additive compound of bismuth by more than or equal to 0.01 percent by mass and less than or equal to 0.7 percent by mass, or alternatively a material with major ingredient zinc, additive bismuth more than or equal to 0.01 percent by mass less than or equal to 0.7 percent by mass, magnesium more than or equal to 0.0003 percent by mass less than or equal to 0.03 percent by mass, and more than or equal to 0.001 percent by mass less than or equal to 0.05 percent by mass of at least one element selected from zirconium, strontium, barium, indium and aluminum; or

(3) To make anode zinc plates by punching out of into given

shapes a thinly rolled sheet from the anode active material of zinc with bismuth added. And, to manufacture manganese dry batteries using anode containers which is made by extrusion in a temperature of 120degrees Centigrade to 210degrees Centigrade; or

(4) A manufacturing method of manganese dry batteries featuring use of to make anode zinc plates by punching into given shapes out of very thinly rolled of a sheet from the anode active material of zinc with additive of bismuth more than or equal to 0.01 percent by mass less than or equal to 0.7 percent by mass, magnesium more than or equal to 0.03 percent by mass and at least any one from zirconium, strontium, barium, indium, and aluminum by more than or equal to 0.001 percent by mass and less than or equal to 0.05 percent by mass. And, to manufacture manganese dry batteries using anode plates made by extrusion of a thinly rolled sheet in a heat of 100degrees Centigrade to 250degrees Centigrade; or

(5) A manufacturing method of battery anode cans featuring manufacture of battery anode containers which anode material consists of average  $8\sim 25\mu\text{m}$  of grain size by press forming in a heat of 120degrees Centigrade to 210degrees Centigrade of zinc alloy anode material of zinc with additive of Bi; or

(6) A manufacturing method of battery anode zinc sheet featuring manufacture of anode zinc sheets which anode material consists of average  $8\sim 25\mu\text{m}$  of crystal grain diameter by thin

rolling in a heat of 100degrees Centigrade to 250degrees Centigrade of a zinc sheet from alloy of zinc with additive of Bi; or

(7) A battery anode material which major ingredient is zinc with additive of bismuth without virtually containing lead, featuring Bi additive more than or equal to 0.01 percent by mass less than or equal to 0.7 percent by mass. And a manufacturing method of battery anode cans referred to above (5) or anode zinc sheets as mentioned above (6); or

(8) Battery anode cans or anode zinc sheets referred in (5), (6), or (7) above featuring use of additive of Mg more than or equal to 0.0003 percent by mass less than or equal to 0.03 percent by mass besides Bi; or

(9) Manganese dry batteries with anode cans or anode zinc sheets referred in (5), (6), (7), or (8) above; or

(10) Battery anode cans with bottom cover made by forming an active material for battery anode which material composition is zinc 98.7 to 99.8 percent by mass, bismuth 0.01 to 0.7 percent by mass, antimony less than or equal to 1ppm, lead less than or equal to 70ppm, and cadmium less than or equal to 20ppm, featuring metallographic average crystal grain diameter in a range of more than or equal to  $8\mu\text{m}$  and less than or equal to  $25\mu\text{m}$ ; grain diameter observed on the cutting cross section of the can wall in the direction of the length (height) and the thickness and measured in the unit of grain diameter of projected crystals on a line drawn in the thickness direction on the screen; or

(11) A thin quadrilateral zinc plate made by forming an anode active material which material composition is zinc 98.7 to 99.8 percent by mass, bismuth 0.01 to 0.7 percent by mass, antimony less than or equal to 1ppm, lead less than or equal to 70ppm, and cadmium less than or equal to 20ppm, featuring metallographic average crystal grain diameter in a range of more than or equal to  $8\mu\text{m}$  and less than or equal to  $25\mu\text{m}$ ; grain diameter observed on the cutting cross section of the can wall in the direction of the length (height) and the thickness, and measured in the unit of grain diameter of projected crystals on a line drawn in the thickness direction on the screen; or

(12) A battery anode can mentioned in (10) above or a battery anode sheet mentioned in (11) made from an anode active material mentioned in (11) but with further additive of magnesium 0.0003 to 0.3 percent by mass; or

(13) A battery anode can referred in (10), (11), or (12) above, featuring metal crystal existing in a range of  $200\mu\text{m}$  width from the outer surface of the anode can and vertically epitaxial against the length height direction which crystal grain diameter is average (O), and metal crystal existing in a range of  $200\mu\text{m}$  width from the inner surface of the can which crystal's metallographic average grain diameter is (I); the grain diameter as observed on the cutting cross section of the can in the length (height) and thickness direction and measured in the unit of the projected grain diameter on a line drawn in the thickness direction



featuring; the ratio of (O/I) is 1.0 to 1.4; or

(14) A manganese dry battery featuring use of a cylindrical battery anode can with bottom cover made by forming an active material for battery anode which composition is zinc 98.7 to 99.8 percent by mass, bismuth 0.01 to 0.7 percent by mass, antimony less than or equal to 1ppm, lead less than or equal to 70ppm, and cadmium less than or equal to 20ppm, and featuring metallographic average crystal grain diameter in a range of  $8\mu\text{m}$  to  $25\mu\text{m}$ ; grain diameter observed on the cutting cross section of the can wall in the length (height), and the thickness direction and measured in the scale of the grain diameter of projected crystal on a line drawn in the thickness direction on the screen; and

(15) A 6F22 laminated dry battery featuring use of a battery anode plate made of an anode zinc sheet from an anode active material which material composition is zinc 98.7 to 99.8 percent by mass, bismuth 0.01 to 0.7 percent by mass, antimony less than or equal to 1ppm, lead less than or equal to 70ppm and cadmium less than or equal to 20ppm; the zinc sheet made by rolling the material to the thickness of 0.2 to 0.7 mm; the anode plate made by punching the zinc sheet into the given quadrilateral shape; the metallographic average crystal grain diameter in a range of  $8\mu\text{m}$  to  $25\mu\text{m}$ ; grain diameter observed on the cutting cross section of the punched plate in the thickness (height) direction and measured in the scale of projected grain diameter of projected crystal on a line drawn in the thickness direction on the screen.

## Detailed Description of the Embodiments

[0008]

Following is the detailed description of the embodiments of this invention.

[0009]

A manganese dry battery consist of active material for anode which major ingredient is zinc, active material cathode which major is manganese dioxide, and electrolyte which major ingredient are zinc chloride and ammonium chloride; three are elements to produce electricity. The battery has the structure like a brief cross section as described in Fig.1 of the drawing. Around a carbon rod (Fig.1 4), the cathode current-collector, and the seal (Fig.1 5) asphalt sealing material or chemically synthesized material is filled in order to shut off air oxygen entering through a gap between the press fitted carbon rod (Fig.1-4) and the seal (Fig.1-5).

[0010] (Cathode)

A cathode for a manganese dry battery in the embodiment of this invention can be made from a cathode active material with manganese dioxide for major ingredient, adding carbon-related material and electrolyte for conductivity improvement. As for manganese dioxide, natural manganese dioxide, chemical processed

manganese dioxide, and electrolytic manganese dioxide is useable, and any of manganese dioxide available on the market is applicable to implement this invention as far as the material is specified for manganese dry batteries.

[0011]

For carbon-related material useable is acetylene black or graphite, any of those normally used for conductive material for batteries.

[0012]

Regarding electrolyte, those generally and publicly known as battery electrolyte can be used; zinc chloride or ammonium chloride solution. But preferable is to apply same electrolyte as used in the manganese dry battery described herein after.

[0013] (Anode)

An anode for a manganese dry battery consists of zinc for major anode active material; the material is molded cylindrically into an anode can. For quadrilateral laminated dry battery 6F22, the material is rolled into a thin sheet and the sheet is punched to quadrilateral plates to make a zinc container.

[0014]

If a bad ductile material for rolling (or deep-drawing) ability is applied to make zinc cans, forming process entails large

cracks on anode cans or plates, which are unusable for batteries. Such an inferior material, if it is used to make zinc plates for 6F22, becomes a cause of cracks at the both sides of a zinc sheet by rolling to thin wall; the plates are unusable and material yield in production is bad. That is the reason of adding lead to zinc in a conventional common practice of. This invention obsoletes lead as additive, and instead proposes a method of press forming and rolling preventing from cracks by adequately setting up processing parameters. Lead has been also used to guard zinc material from corrosion by electrolyte. This invention recommends to apply such element as bismuth instead lead to improve corrosion resistance.

[0015]

An anode of above-mentioned quality is obtainable from an anode material by using bismuth-added alloy and by optimizing corrosion-resistant property, fabrication method, or crystal structure.

Following explains Anode A, Anode B, and Anode C as recommendable examples for embodying this invention.

[0016] (Anode A)

The Inventor's study detected significant correlation between reliability of a battery with an anode from cadmium-added zinc alloy and decrease amount by corrosion of the battery anode. A test of corrosion-decrease under conditions close to actual use

of a battery produced a result that an anode material which gave good test data showed competent effect in reliability of the battery. This means that; material easily corrodible with electrolyte is essentially not applicable to batteries. Important is realistic effective test method to evaluate corrosion resistance of materials to select.

[0017]

This invention proposes a corrosion testing in a mode closer to practical usage by applying electrolyte with addition of particular material. That enabled the Inventor's team to decide optimum material to use.

[0018]

The active anode material in the embodiment of this invention is zinc as major ingredient with addition of bismuth. Preferable amount of bismuth to add is within a range from 0.01 percent by mass to 0.7 percent by mass. An amount less than or equal to 0.01 percent by mass is short to effect corrosion resistance. And, an amount more than or equal to said range does not give an effect for the amount added, and deteriorates discharge characteristic.

[0019]

Specific amount of additive bismuth preferable depends on the kind of manganese dioxide to be mixed into cathode compound as the cathode active material. In case of natural manganese

dioxide which usually contains much of impurities, addition of bismuth is required more than or equal to 0.10 percent by mass of the zinc amount. In case of electrolyte manganese dioxide which usually contains very little impurities, addition of just more than or equal to 0.01 percent by mass gave no problem, according to a test by the Inventor. Addition exceeding 0.7 percent by mass gave no effect or improvement for the amount put in and that proved to be only uneconomical.

[0020]

In the embodiment of this invention, besides bismuth suitable is to add to zinc any one or two combined of such elements as magnesium, barium, strontium, indium, zirconium, and aluminum. Addition of magnesium or zirconium especially recommendable in respect of enhancing process ability of anode zinc.

[0021]

Preferable amount of magnesium to add is 0.0003 to 0.03 percent by mass. For an anode can or an anode zinc plate hardness is necessary for secured sealing, and magnesium additive is deemed to be within a range of 0.0003 to 0.03 percent by mass. Excessive addition causes a can or a plate friable and is not desirable.

[0022]

Preferable amount of those additives as barium, strontium, indium, zirconium, and aluminum is from 0.001 to 0.05 percent by

mass. Less amount of those additives than that range is not desirable because cracks may occur on cans and plates if a processing heat rises over 210degrees Centigrade, a conventional standard level of heat. Additive amount exceeding that range is undesirable, either, for corrosion resistance.

[0023]

Whereas corrosion test by the conventional method for addition of indium to anode material by 0.1 percent by mass showed a level of corrosion resistance equivalent to that of the material with lead additive, a test this in invention, a practical and convenient method using a publicly available standard impurity additive, revealed a corrosion amount with the same material (indium 0.1 percent by mass) approximately 5 times as much as (21 mg/10cm<sup>2</sup>) with the material containing lead. The result meant a battery using the material indium 0.1 percent by mass added might involve practical problems, and in fact the battery made out with this material disclosed short battery life hardly useable, through evaluation test by repetition of discharge and halt. A preferable average crystal grain diameter of foregoing anode active material is less than or equal to 20  $\mu$ m. An average crystal grain diameter more than or equal to 20  $\mu$ m acts to lower corrosion resistance against electrolyte and increase corrosion amount to wear the can wall quickly.

[0024] (Manufacturing method of Anode A)

In the foregoing description, a cylindrical manganese dry battery and a quadrilateral laminated dry battery were taken for example to embody this invention. But embodiment is not restricted to those types. The anode active material is also applicable to board (sheet) types or cylindrical with bottom cover types of batteries.

[0025]

One of features in embodying this invention is heat control of the material surface in extrusion which is a general process to form a zinc sheet into a cylindrical can with bottom cover. If a material surface temperature exceeds 210degrees Centigrade, sometimes cracks happen on the material. If the material is processed in lower temperature than 120degrees Centigrade, dimensions of the finished cans tend to exceedingly vary, which is unacceptable.

Heat control is necessary in narrower range than that for extruding a conventional lead added material (100degrees Centigrade to 260degrees Centigrade). However, this heat range (100degrees Centigrade to 260degrees Centigrade) is applicable to the anode material with additive of any one of magnesium, zirconium, strontium, and barium to zinc. Likewise, 120degrees Centigrade to 210degrees Centigrade is a preferable heat range for rolling process of anode zinc sheets, but a heat range 100degrees Centigrade to 260degrees Centigrade can applied to the



material with additive of any one of magnesium, zirconium, strontium, and barium to zinc.

[0026]

Manufacturing process of anode cans is following in embodying this invention.

First: ingot by melting zinc alloy

Second: hot rolling to 4 to 8 mm sheet

Third: blanking a sheet to disk shape or hexagonal pellets

Fourth: impact punching pellets with a round whole die and a cylindrical punch

Anode zinc sheet

First and second: same as above

Third: further hot rolling to 0.3 to 0.7 mm sheet

Fourth: (1) blanking to given shape of plates; or

(2) coating either side of the sheet with conductive paint, dry up, and blanking

[0027] (Corrosion resistance test for Anode A)

Following explains about the corrosion resistance test of an anode zinc material.

First: (1) Cut out a 10cm<sup>2</sup> piece of a finished cylindrical can with bottom cover

(2) Cut out same size of piece out of other type of anode container for manganese dry battery

Second: dipping the cut-out piece in electrolyte as

specified in 0026 below with added nickel 2.9 ppm, cobalt 0.40 ppm, and copper 0.86ppm in a constant temperature chamber. Laying still for 66 hours in 45degrees Centigrade.

Third: Measuring an amount of decrease in weight by corrosion

Fourth: Decrease less than or equal to 3.8 mg

- The zinc material O.K.
- More than or equal to, (including) 3.8 mg N.G.

[0028]

The electrolyte used for above test is composed of 26 percent by mass zinc chloride and 1.5 percent by mass ammonium chloride solved in pure water. Regarding the additives above mentioned nickel, cobalt, and copper, recommended to use the standard liquid generally used for element analysis by atomic absorbance method, which liquid is publicly available and practically convenient to apply.

[0029]

The amount of nickel, cobalt and copper for the test represents an accelerated test of an anode material for an amount of elution from electrolyte from 100% natural manganese dioxide after storage of a battery for about one (1) year in a normal temperature; the amount of nickel, cobalt and copper is equivalent to elution of the impurities into electrolyte during 10 days in 60degrees Centigrade constant temperature. The ratio of natural

manganese dioxide and electrolyte is approximately 1: 2 at this time. Storage a battery for one (1) year in a normal temperature stands for a corrosion test for 66 hours in 60degrees Centigrade.

This invention presents foregoing corrosion test parameter taking into account abovementioned condition and result.

[0030] (Anode B)

In this invention zinc is the major ingredient of anode active material. Bismuth is the additive.

No lead is added. The material's average crystal grain diameter is 8 to 25  $\mu$ m. The material features superior corrosion resistance and long life property.

[0031]

Therefore in case of applying natural manganese dioxide for cathode active material it is desirable to add bismuth by more than or equal to 0.1 percent by mass and less than or equal to 0.7 percent by mass. On the other hand, an amount more than or equal to 0.7 percent by mass does not give any extra merit for corrosion resistance for an additional amount just incurring extra material cost. Preferable amount of magnesium to use together is more than or equal to 0.0003 percent by mass. A lesser amount than 0.0003 percent by mass is problematic in keeping necessary hardness of cans and plates, while more than or equal to 0.03 percent by mass acts to make a zinc sheet undesirably hard causing friability against processing impact.

[0032]

Forming anode material into anode zinc cans: ingot by casting zinc with additives bismuth and other; rolling ingot to a zinc sheet 4 to 8 mm thick; punching the sheet to pellets; deep-drawing the pellets to cans.

[0033]

Apply pressure to the punch can be any generally exercised, not specific to making battery cans.

For example, 100t can be enough for deep drawing pellets of 6 mm thick and 31 mm outer dimension. Processing heat in a range of 120 to 210degrees Centigrade is suitable for rolling a 4 to 8 mm sheet to a 0.3 to 0.7 mm thin sheet for 6F22 anode zinc plates.

[0034]

The anode cans and plates including thin one for 6F22 thus made out are free from crack and competently corrosion resistant, being 8 to 25  $\mu$ m of the metallographic average crystal grain diameter of those cans and plates.

[0035] (Anode C)

The material for this case of anode cans and plates is alloy of zinc major material, bismuth, and inevitably contained lead in zinc ground metal, antimony, and cadmium limited to a specified level.

[0036]

Bismuth additive is for corrosion resistance. Preferable amount to add is 0.01 percent by mass to 0.7 percent by mass. More preferable amount to add is 0.1 percent by mass to 0.7 percent by mass. If the bismuth additive amount is less than or equal to above mentioned range, it is not preferable in the view point of corrosion resistance. On the other hand, if the bismuth additive amount is more than or equal to above mentioned range, it is not preferable because the cost of raw material increases due to the less impact of additive to the corrosion resistance.

The preferable amount of the bismuth additive depends on the kind of manganese dioxide added to cathode material as cathode active material. If natural manganese dioxide which naturally contains much of impurities is used for cathode material, more than or equal to 0.1 percent by mass is necessary. If electrolytic manganese dioxide which contains very little impurities, more than or equal to 0.001 percent by mass is adequate. More than or equal to 0.7 percent by mass is just uneconomical because the improvement effect that reflects the additive amount is not obtained.

[0037]

If zinc alloy contains antimony as accompaniment impurities exceeding 1ppm, it deteriorates corrosion resistance, resulting inferior leakage resistant property. Furthermore, it is preferable that the amount of lead is less than or equal to 70ppm,

and that the amount of cadmium is less than or equal to 20ppm.

Mass scraping of manganese dry batteries made from alloy containing the elements beyond those limits may cause significant environmental pollution and must be avoided.

[0038]

In this example of implementing the invention, magnesium can be added to zinc besides bismuth.

Additive magnesium for process ability in deep-drawing of anode cans and material hardness more than or equal to 0.0003 percent by mass, less than or equal to 0.03 percent by mass.  
Less amount than the range; no good for process ability  
More amount than the range; too hard, friable to process impact

[0039]

Average crystal grain diameter of anode active material as foregoing preferable metallographic average crystal grain diameter is from  $8\mu\text{m}$  to  $25\mu\text{m}$ . A larger grain length deteriorates corrosion resistance against electrolyte containing impurities and not desirable. Generally known is that smaller crystal grains are, the better for corrosion resistance, thin wall process-ability, and deep-drawing. And, imaginable is to employ such means as quenching in making ingot in order to obtain smaller crystal grains than  $8\mu\text{m}$ . However, that can be hardly practicable manufacturing mean of manganese dry battery anode zinc material

in view of extra capital investment and complexity of work involved for not substantial improvement of the products.

[0040]

Measuring crystal grain diameter is a job involved in implementing this invention. A grain diameter meant here is the diameter of crystal epitaxial vertically to the length (height) direction of an anode can. Many of crystals are of oval shapes or oval-like shapes, as observed in the metal structure of a zinc can, since the zinc sheet for a can undergoes deep-drawing process. Naturally vertical length and horizontal length of crystal grains are different. But it is possible to measure grain diameter of crystal epitaxial vertically to length (height) direction of a can wall, and to control grain diameter to achieve the effect of this invention. In case of a zinc plate, the work is to measure diameter of the crystal grain epitaxial vertically to both of two flat faces, and to control the value thereof. If the grain diameter is more than or equal to  $25.1\mu\text{m}$ , enough corrosion resistance is not obtainable. No material with grain diameter less than or equal to  $7.8\mu\text{m}$  was not available.

[0041]

In this embodiment of the invention, if the grain diameter is more than or equal to  $25.1\mu\text{m}$ , enough corrosion resistance is not obtainable. No material with grain diameter less than or equal

to  $7.8\mu\text{m}$  was not available.

This invention deals with O/I ratio of crystal grain diameter as an important improvement point.

Looking at metallographic crystal grain in an area of inside an anode can wall (the side contacting the separator: I), within  $200\mu\text{m}$  from the contacting point, and the same in the area of out of the can wall (the side contacting the insulating cover tube: O)  $200\mu\text{m}$  from the outer surface. The lesser O/I ratio is the smaller variation of material property is; caliber for stability of anode material quality. The O/I ratio has been more than or equal to 1.4 with conventional anode material. The material created with this invention presented the ratio from 1.1 to 1.4. By narrowing variation of crystal grain diameter at both inside and outside anode can wall, even when a battery reaction and wear of the zinc significantly goes on, the anode zinc can keeps its original property longer than a conventional battery one, and maintains corrosion resistance against wear from the inside can wall by discharge reaction.

[0042] (Manufacturing method: Anode C)

Selection of zinc ground metal should be done in respect of purity more than or equal to 99.5%, with impurities (inevitable accompaniment) of lead less than or equal to 70ppm, antimony less than or equal to 1ppm, and cadmium less than or equal to 20ppm.

Melting the zinc ground metal at  $470 \pm 50$  degrees Centigrade,



compounding bismuth and churning, ingot is made out. Hot rolling of the ingot at surface temperature  $150 \pm 50$ degrees Centigrade processes a sheet to a designated thickness.

[0043] (Making cans and plates)

Can:

Punching the zinc sheet to hexagonal or circular zinc pellets; deep-drawing the zinc pellet in 120degrees Centigrade to 210degrees Centigrade (preferably  $150 \pm 30$ degrees Centigrade) on pellet surface to form a cylinder with bottom cover placing the pellet on a die with round hole and press hitting a cylindrical punch with impact; trimming the formed canto a designated measurement for a battery. If magnesium is added to alloy, temperature of pellet surface can be 100degrees Centigrade to 250degrees Centigrade (desirably 150degrees Centigrade  $\pm 50$ degrees Centigrade), and process ability is same as for sheet and a pellet from a lead-added alloy conventionally used.

Plate for 6F22:

Further rolling a zinc sheet to 0.3 to 0.7 mm thin zinc sheet; coating conductive paint onto either side; drying the coat and punching to a designated shape.

[0044] (Electrolyte)

Solutions of pure water with zinc chloride or ammonium

chloride are used for electrolyte of manganese dioxide dry batteries. Mixture of the two materials can be used. Concentration in a range generally practiced is applicable: mixture of 20 to 30 percent by mass zinc chloride solution plus 1.0 to 3.0 percent by mass ammonium chloride solution. Deviation from such a range of concentration might deteriorate leakage proof or discharge characteristic of the battery.

[0045] (Separator)

Separator is made of separator paper alike craft paper with a coat of wet expandable paste to hold back electrolyte.

Suitable paste is any of natural starch, chemical starch, gua-gum or synthesized paste.

[0046] (Manufacturing method of a battery)

In embodiment of this invention, a manganese dry battery is made in a following way. But that is an example method, and different methods are applicable as far as they are in line of principle and context of this invention.

After weighing cathode active material which has manganese dioxide for major substance, and weighing conductive material such as acetylene black or graphite, dry compound these materials. Then, spray electrolyte to the mixed material, and wet compound the mixed material to form the cathode material compound powder.

[0047]

Make cylindrical shaped zinc can with bottom by press forming the above-mentioned zinc alloy of this embodiment at the temperature between 100degrees Centigrade and 250degrees Centigrade. Insert a cylindrical separator and a dish shaped bottom insulating paper into the inner wall of the zinc can, and insert formed cathode compound into the cylindrical separator and a dish shaped bottom insulating paper. Mount a piece of pressure paper receiving atop the compound, and press so as to adhere the zinc can, the separator and the cathode compound tightly each other. After that, press inserting a carbon rod which will be the current collector into the center of cathode compound, and make the separator wet by the electrolyte eluted from the cathode. Then coat sealing material onto the contacting faces of a plastic sealing plate and the carbon rod. After putting the sealing plate onto the can opening, put a bottom cover plate for the negative terminal and a bottom ring onto the can bottom. Cover the battery overall with a piece of heat shrink tube. After putting the positive terminal plate contacting the carbon rod and plastic seal, crimp seal whole can with the medium of a insulating ring. That completes a manganese dry battery. Make a zinc sheet 0.5 mm thick by rolling zinc alloy of this embodiment in 100degree Centigrade to 250degree Centigrade. Coat the sheet with conductive material and dry up. Then, punch the sheet to the designated structure of plate. form a piece of plastic tube to cup shape, therein putting the zinc plate to. Insert of an adhesive coated separator. Form the compound in the shape of the pellet, and fill them above the separator.

Pressing the compound, shrinking the tube, a cell is made out. After laminating 6 cells and tightening overall with the shrink tube, compress bonding the bottom and top terminal onto the top and the bottom of the laminates of 6 cells, and shrinking the tube further. Put the whole into a metal jacket together with a current collection strip, and clip sealing the upper and the lower opening. That completes a quadrilateral laminated manganese dry battery.

[0048] (Example A)

Following is detailed description of an Example.

(1) Obtained was a battery anode zinc material from a lot of zinc ground metal purity more than or equal to 99.99 percent by mass, without adding lead but adding specified amount of bismuth or bismuth plus strontium, or bismuth plus barium, or bismuth plus zirconium. The zinc ground metal inevitably contained impurities such as copper, iron, and cadmium on the ppm order.

(2) Made were zinc pellets in designated dimensions out of a sheet made by hot rolling of the zinc alloy.

(3) Made were zinc cans 0.35 mm thick with bottom cover out of the zinc pellets by deep-drawing. Surface temperature of the work material was measured with laser pointer of Yokogawa digital heat emission thermometer 530/04.

Visually inspected finish condition of the cans, and using a microscope observed was surface condition, dent or cracks. Further checked was metal structure and if any or no cracks.

(4) Made out was a R20 manganese dry battery with the zinc can. Then conducted was corrosion test of the zinc material and evaluation of the battery.

[0049] (1) Corrosion test of the anode zinc material (corrosion resistance test)

Prepared were test samples by cutting piece  $10\text{cm}^2$  out of the finished cans; A sample 0.3 mm thick, 10.0 mm wide, 50.0 mm long. Polished was the sample surface up to mirror face with the sand paper #400, #600, #800, #1000 and #1200, degreased, weighed and dipped into the prepared battery electrolyte. Defined the weight decreased after laying still in a constant temperature water chamber filled with electrolyte for 66 hours at 45degrees Centigrade was defined as the decrease by corrosion .The electrolyte used was normal battery electrolyte consisting of zinc chloride 25 percent by mass and ammonium chloride 2.0 percent by mass by adding standard liquid available in the market containing nickel, cobalt and copper in a composition to adjust concentration of the electrolyte to nickel 2.9ppm, cobalt 0.40ppm, and copper 0.86ppm. To deter oxygen remaining unsolved in the chamber affect electrolyte property, injected was argon gas to bubble for 10 minutes, and that was the designated test liquid.

Tested were 6 samples with the liquid and obtained was average value of corrosion decrease amount (weight).

[0050] (2) Evaluation of battery property

Following is the composition of the anode compound used for a battery under evaluation.

(I) 50 parts by mass of electrolytic manganese dioxide which purity more than or equal to 92% (impurity: copper below 0.0005 percent by mass, iron below 0.02 percent by mass, and lead below 0.0005 percent by mass)

(II) 9 parts by mass of acetylene black containing ash 0.01 percent by mass

(III) 26 percent by mass of zinc chloride

(IV) 49 parts by mass of electrolyte consisting 26 percent by mass of zinc chloride, 1.5 percent by mass of ammonium chloride, with nickel 2.9ppm, cobalt 0.40ppm, and copper 0.86ppm to adjust concentration - homogeneous mixture of above: Cathode compound A; or

(V) with 10 times as much as impurity amount in (I) to adjust concentration nickel 29.0ppm, cobalt 4.0ppm, and copper 8.6ppm - Cathode compound B; or

(VI) without adjusting additives - Cathode compound C

[0051]

The separator prepared is a piece of craft paper coated with chemical starch of, cross linkage ether of cornstarch.

Using the abovementioned anode zinc material, made out was R20 manganese dry battery. The attached drawing 1 describes this battery. 1 refers to the anode zinc can, 2 the separator, 3 the cathode compound, 4 the carbon rod for collecting current, 5 the

gasket, 6 the positive terminal, 7 the negative terminal, 8 the insulating tube, 9 outer cover.

Coated was the contact faces of the carbon rod 4 and the seal with asphalt seal material to shut out oxygen to enter through a gap between press inserted carbon rod 4 and the gasket 5.

After storing the battery thus made in a constant temperature chamber of 20degrees Centigrade  $\pm$  2degrees Centigrade for 10 days and further storing in a constant temperature chamber in 40degrees Centigrade for 30days, the battery was discharged with a load of 40 ohm ( $\Omega$ ) for 4 hours a day in a room temperature. Subsequently evaluated was life characteristics at the time of 1.1 V, and obtained was relative values to 100 a standard index that stands for the characteristics of conventional and currently available batteries. The number of the samples for evaluation was 9 pieces of R20 finished in this work. For comparison and reference purpose made out were same type battery using anode zinc cans which material 0.4 percent by mass of lead was added to and, conventional zinc cans, and one more battery using anode cans which material 0.1 % indium was added to and no lead.

Also tried was to make a battery with an anode can which material 0.3 % indium added to and no lead, however, too much cracks appeared during manufacturing and no electrodes or batteries were obtainable worth while evaluation.

[0052] (Example A1 to A15, Comparative Example A1 to A4, and

## Reference Example A1)

The table A1 herein below indicates result of the corrosion test by foregoing method of the anode active materials with different addition of bismuth, indium, magnesium, zirconium, strontium and barium.



[0053] Table A1

	Bismuth Added amount	Added ingredient of amount	Decrease amount by corrosion	Decrease amount by corrosion Unbiased variance value
Example A1	0.10	-	3.8	0.0147
Example A2	0.20	-	2.4	0.0110
Example A3	0.30	-	2.0	0.00567
Example A4	0.40	-	1.6	0.00267
Example A5	0.50	-	1.3	0.00667
Example A6	0.70	-	1.1	0.00567
Comparative example A1	-	-	12.0	1.10
Comparative example A2	0.05	-	5.8	1.14
Comparative example A3	1.00	-	1.1	0.00400
Comparative example A4	-	In0.10	21.0	7.10
Reference example A1	-	Pb0.40	4.2	0.00187
Embodiment example A7	0.20	Mg0.0003	2.4	0.0107
Embodiment example A8	0.20	Mg0.001	2.5	0.00967
Embodiment example A9	0.20	Mg0.003	2.6	0.0107
Example A10	0.20	Zr0.001	2.3	0.00800
Example A11	0.20	Zr0.05	2.2	0.00800
Example A12	0.20	Sr0.001	2.8	0.0160
Example A13	0.20	Sr0.05	3.1	0.0107
Example A14	0.20	Ba0.001	3.0	0.0627
Example A15	0.20	Ba0.05	3.9	0.311

[0054]

The result shows corrosion decrease less than or equal to 3.9 mg for every Example of this invention, whereas the comparative example A1, no additives of bismuth or any, indicates 12.0 mg of decrease. It is obvious that corrosion resistance was significantly improved in the Examples.

[0055] (Example A18 to A32, Comparative Example A6 to A15, Reference Example A3)

The anode zinc cans were made from materials with additives

bismuth, magnesium, or zirconium, processed in different temperatures.

Checked was thickness of the bottom and crack of the cans overall, and obtained result as shown in Table A2.

[0056] Table A2

	Bismuth added amount	Added element & amount	Material temperature in processing	Can bottom thickness average value	Bottom thickness unbiased variance value	Number of crack
Comparative example A6	0.30	-	91	0.53	6.93E-4	0
Example A18	0.30	-	118	0.50	0.267E-4	0
Example A19	0.30	-	153	0.50	0.178E-4	0
Example A20	0.30	-	211	0.50	0.278E-4	0
Comparative example A7	0.30	-	232	0.50	0.233E-4	1
Comparative example A8	0.30	Mg0.001	94	0.52	2.68E-4	0
Example A21	0.30	Mg0.001	111	0.50	0.233E-4	0
Example A22	0.30	Mg0.001	156	0.50	0.178E-4	0
Example A23	0.30	Mg0.001	252	0.50	0.456E-4	0
Comparative example A9	0.30	Mg0.001	278	0.50	0.233E-4	2
Comparative example A10	0.30	Mg0.003	94	0.52	2.94E-4	0
Example A24	0.30	Mg0.003	110	0.50	0.267E-4	0
Example A25	0.30	Mg0.003	154	0.50	0.100E-4	0
Example A26	0.30	Mg0.003	256	0.50	0.400E-4	0
Comparative example A11	0.30	Mg0.003	274	0.50	0.456E-4	2
Comparative example A12	0.30	Zr0.001	92	0.51	2.54E-4	0
Example A27	0.30	Zr0.001	113	0.50	0.233E-4	0
Example A28	0.30	Zr0.001	152	0.50	0.222E-4	0
Example A29	0.30	Zr0.001	255	0.50	0.233E-4	0
Comparative example A13	0.30	Zr0.001	275	0.50	0.278E-4	3
Comparative example A14	0.30	Zr0.05	93	0.51	2.67E-4	0
Example A30	0.30	Zr0.05	110	0.50	0.278E-4	0
Example A31	0.30	Zr0.05	153	0.50	0.178E-4	0
Example A32	0.30	Zr0.05	254	0.50	0.267E-4	0
Comparative example A15	0.30	Zr0.05	271	0.50	0.900E-4	4
Reference example A3	-	Pb0.40	255	0.50	0.267E-4	0

[0057]

As the result shown in Table A2 proves, the method taken in the Examples realized very little variance of the can bottom thickness and very few cracks presenting superior process-ability.

[0058] (Example A33 to A43, Comparative Example A16 to A17,

## Reference Example A4)

Evaluation was done for the batteries with anode cans from anode active material with additives of bismuth, indium, magnesium, or zirconium to zinc.

The result is shown in Table A3 below.

[0059] Table A3

	Cathode compound	Bismuth added amount	Added ingredient & amount	Corrosion decrease	Corrosion decrease unbiased variance value	Life relative value	Life relative value unbiased variance value
Example A33	C	0.01	-	8.9	0.754	100	1.42
Example A34	C	0.10	-	3.8	0.0147	100	0.0600
Example A35	C	0.20	-	2.4	0.0110	100	0.0553
Example A37	C	0.30	-	2.0	0.00567	100	0.0744
Example A38	C	0.40	-	1.6	0.00267	100	0.0936
Example A39	C	0.50	-	1.3	0.00667	100	0.0600
Example A40	C	0.70	-	1.1	0.00567	100	0.0800
Comparative example A16	C	-	-	12.0	1.10	99	2.55
Comparative example A17	C	-	In0.10	21.0	7.10	95	19.1
Reference example A4	C	-	Pb0.40	4.2	0.00187	100	0.0886
Example A41	C	0.30	Mg0.003	2.0	0.00267	100	0.0675
Example A42	C	0.30	Zr0.05	2.0	0.00667	100	0.0675
Example A43	C	0.30	Zr0.001	1.9	0.00567	100	0.0611

[0060]

As Table A3 describes, the evaluation result revealed that the batteries made in embodying this invention have longer life than the batteries from the material omitting additive of bismuth (Comparative example A16) and the material with sole additive of indium (Comparative example A17) to zinc.

And, the life of the batteries by this invention was no less than or equal to that of conventional batteries from the material

with lead added to zinc.

[0061] (Example A44 to A54, Comparative Example A18 to A19, Reference Example A5)

Life test of batteries made of;

- anode cans from anode active materials with different additives indium, magnesium, zirconium, strontium, or barium, beside bismuth to zinc.
- Cathode compound with additives nickel 2.9ppm, cobalt 0.40ppm, and copper 0.86ppm to manganese dioxide.

[0062] Table A4

	Cathode compound	Bismuth added amount	Added ingredient & amount	Corrosion decrease	Corrosion decrease unbiased variance value	Life relative value	Life relative value unbiased variance value
Comparative example A18	A	-	-	12.0	1.10	69	21.0
Example A44	A	0.01	-	8.9	0.754	90	30.8
Example A45	A	0.10	-	3.8	0.0147	100	0.776
Example A46	A	0.20	-	2.4	0.0110	101	0.138
Example A47	A	0.30	-	2.0	0.00567	101	0.778
Example A48	A	0.40	-	1.6	0.00267	101	0.482
Example A49	A	0.50	-	1.3	0.00667	101	0.778
Example A50	A	0.70	-	1.1	0.00567	102	0.147
Comparative example A19	A	-	In0.10	21.0	7.10	66	63.8
Reference example A5	A	-	Pb0.40	4.2	0.00187	100	0.251
Example A51	A	0.30	Mg0.003	2.0	0.00267	101	0.485
Example A52	A	0.30	Zr0.05	2.0	0.00667	100	2.26
Example A53	A	0.30	Sr0.005	2.3	0.0011	101	3.11
Example A54	A	0.30	Ba0.05	3.7	0.126	100	6.75

[0063]

As Table A4 depicts, the batteries by this invention have life not less than or equal to that of the lead-contained battery (Reference example A5) and have longer life than the batteries of Comparative examples do.

[0064] (Example A55 to A61, Comparative Example A20 to A23, Reference Example A6)

Life test of batteries made of;

- anode cans from anode active materials with different additives indium, magnesium, zirconium, strontium, or barium, beside bismuth to zinc.
- Cathode compound with additives nickel 2.9ppm, cobalt 0.40ppm, and copper 0.86ppm to manganese dioxide.

Result in Table A5.

[0065] Table A5

	Cathode compound	Bismuth added amount	Added ingredient & amount	Corrosion decrease	Corrosion decrease unbiased variance value	Life relative value	Life relative value unbiased variance value
Comparative example A20	B	0.01	-	8.9	0.0754	78	64.7
Comparative example A21	B	0.10	-	3.8	0.0147	100	3.28
Example A55	B	0.20	-	2.4	0.0110	102	2.25
Example A56	B	0.30	-	2.0	0.00567	101	0.944
Example A57	B	0.40	-	1.6	0.00267	101	1.36
Example A58	B	0.50	-	1.3	0.00667	101	0.75
Example A59	B	0.70	-	1.1	0.00567	102	0.500
Reference example A6	B	-	Pb0.40	4.2	0.00187	100	6.00
Example A60	B	0.30	Mg0.003	2.0	0.00267	102	2.50
Example A61	B	0.20	Zr0.05	2.2	0.00800	102	2.78
Comparative example A22	B	0.30	Sr0.05	2.5	0.00227	98	6.78
Comparative example A23	B	0.20	Ba0.05	3.9	0.311	82	69.0

[0066]

As Table A5 indicates, the batteries of this invention have life not less than that of the lead-contained battery (Reference example A6) and have longer life than the batteries of Comparative examples do.

[0067] (Example A')

Following is detailed description of an Example.

Obtained was a battery anode zinc material from a lot of zinc ground

metal purity more than or equal to 99.99 percent by mass, without adding lead and adding specified amount of bismuth, or bismuth plus strontium, or bismuth plus barium, or bismuth plus magnesium, or bismuth plus zirconium. The zinc ground metal inevitably contains impurities such as copper, iron, and cadmium on the ppm order. Made were zinc pellets in designated dimensions out of a sheet made by hot rolling those said zinc materials. Rolling further this sheet of material to get a thin wall sheet. The sheet of thin wall was checked if finish was O.K and had no crack or dent. Subsequently made out were 50 pieces of 6F22 laminated manganese dry battery using different zinc cans.

Then the result of corrosion test was conducted on the anode zinc materials and characteristic evaluation of materials was recorded with 50 batteries.

[0068] (1) Corrosion test (corrosion resistance check) of anode zinc material used for Example A'

Test samples were prepared; each 0.5 mm thick, 10.0 mm wide, 50.0 mm long, by cutting out of the 0.5mm thick zinc sheet made by foregoing process. The samples were polished up to mirror face with the sand paper #400, #600, #800, #1000 and #1200, degreased, weighed and dipped into the prepared battery electrolyte. Defined was the weight decrease after laying still for 66 hours at 45degrees Centigrade as the decrease by corrosion. The electrolyte used was normal battery electrolyte consisting of zinc chloride 25 percent by mass and ammonium chloride 2.0 percent by mass, adding standard



liquid available from market containing nickel, cobalt and copper in a way to adjust concentration of electrolyte to nickel 2.9ppm, cobalt 0.40ppm, and copper 0.86ppm. To deter oxygen remaining unsolved affect electrolyte property, injected argon gas to bubble for 10 minutes. That was the designated test liquid. Tested 6 samples with the liquid and obtained average value of corrosion decrease.

[0069] (2) Evaluation of material property by finished batteries

Following is the composition of the anode compound used for a battery under evaluation.

(I) 50 parts by mass of electrolytic manganese dioxide which purity more than or equal to 92% (impurity: copper below 0.0005 percent by mass, iron below 0.02 percent by mass, and lead below 0.0005 percent by mass)

(II) 9 parts by mass of acetylene black containing ash 0.01 percent by mass

(III) 26 percent by mass of zinc chloride

(IV) 49 parts by mass of electrolyte consisting 26 percent by mass of zinc chloride, 1.5 percent by mass of ammonium chloride, with nickel 2.9ppm, cobalt 0.40ppm, and copper 0.86ppm to adjust concentration - homogeneous mixture of above: Cathode compound A; or

(V) with 10 times as much as impurity amount in (I) to adjust concentration nickel 29.0ppm, cobalt 4.0ppm, and copper 8.6ppm - Cathode compound B; or

(VI) without adjusting additives - Cathode compound C

[0070]

The separator prepared is a piece of craft paper coated with chemical starch of cross linkage ether of cornstarch.

Using the abovementioned anode zinc material, made out 6F22 quadrilateral laminated manganese dry battery. The attached drawing 1 describes that battery.

After storing the battery in a constant temperature chamber of 20degrees Centigrade  $\pm$  2degrees Centigrade for 10 days and further storing in a constant temperature chamber in 45degrees Centigrade for 30days, the battery was discharged with a load of 620 ohm ( $\Omega$ ) for 2 hours a day in a room temperature. Subsequently evaluated were life characteristics at the time of 6.6 V, and obtained was relative values to 100 the standard caliber representing the characteristic value of conventional and currently available batteries.

For comparison and reference made out were same type batteries using anode zinc cans which material 0.4 percent by mass of lead was added to, conventional zinc cans, and another using anode cans where 0.1 % indium was added and no lead.

Also tried to make a battery with an anode can which material 0.3 percent by mass indium was added to and no lead, however, too much cracks appeared during process and no electrode or batteries

were obtainable worth while evaluation.

[0071] (Example A62 to A76, Comparative Example A24 to A27, Reference Example A7)

Corrosion resistance test was conducted for the anode active materials with additives of bismuth, indium, magnesium, zirconium, strontium, or barium by each amount indicated in Table AA1 below.

[0072] Table AA1

	Bismuth Added amount	Added ingredient of amount	Decrease amount by corrosion	Decrease amount by corrosion Unbiased variance value
Example A62	0.10	-	3.9	0.0150
Example A63	0.20	-	2.3	0.0112
Example A64	0.30	-	1.9	0.00572
Example A65	0.40	-	1.7	0.00268
Example A66	0.50	-	1.4	0.00681
Example A67	0.70	-	1.2	0.00601
Comparative example A24	-	-	12.5	1.18
Comparative example A25	0.05	-	6.0	1.15
Comparative example A26	1.00	-	1.2	0.00412
Comparative example A27	-	In0.10	22.2	7.50
Reference example A7	-	Pb0.40	4.5	0.00190
Example A68	0.20	Mg0.0003	2.3	0.0118
Example A69	0.20	Mg0.003	2.4	0.0090
Example A70	0.20	Mg0.03	3.8	0.0181
Example A71	0.20	Zr0.001	2.4	0.009
Example A72	0.20	Zr0.05	2.1	0.007
Example A73	0.20	Sr0.001	2.7	0.0172
Example A74	0.20	Sr0.05	3.0	0.0118
Example A75	0.20	Ba0.001	3.2	0.0712
Example A76	0.20	Ba0.05	3.7	0.391

[0073]

The result shows corrosion decrease less than or equal to 3.9 mg for every Example, whereas the comparative example A24, no additives bismuth or any, indicates 12.5 mg of decrease. It is obvious that corrosion resistance was significantly improved in the Examples.

[0074] (Example A77 to A91, Comparative Example A28 to A37, Reference Example A8)

The anode zinc electrode were made from materials with additives bismuth, magnesium, or zirconium, processed in

different temperature.

Checked thickness and crack of the sheets, and obtained result as shown in Table AA2.

[0075] Table AA2

	Bismuth added amount	Added element & amount	Material temperature in rolling	Number of crack
Comparative example A28	0.30	-	99	0
Example A77	0.30	-	121	0
Example A78	0.30	-	161	0
Example A79	0.30	-	222	0
Comparative example A29	0.30	-	241	2
Comparative example A30	0.30	Mg0.003	95	0
Example A80	0.30	Mg0.003	113	0
Example A81	0.30	Mg0.003	161	0
Example A82	0.30	Mg0.003	255	0
Comparative example A31	0.30	Mg0.003	281	4
Comparative example A32	0.30	Mg0.03	96	0
Example A83	0.30	Mg0.03	112	0
Example A84	0.30	Mg0.03	161	0
Example A85	0.30	Mg0.03	261	0
Comparative example A33	0.30	Mg0.03	281	3
Comparative example A34	0.30	Zr0.001	95	0
Example A86	0.30	Zr0.001	114	0
Example A87	0.30	Zr0.001	156	0
Example A88	0.30	Zr0.001	261	0
Comparative example A35	0.30	Zr0.001	282	5
Comparative example A36	0.30	Zr0.05	94	0
Example A89	0.30	Zr0.05	112	0
Example A90	0.30	Zr0.05	163	0
Example A91	0.30	Zr0.05	255	0
Comparative example A37	0.30	Zr0.05	273	7
Reference example A8	-	Pb0.40	265	0

[0076]

As the result shown in Table AA2 proves, the method taken in the Examples realized superior process-ability with very few cracks.

[0077] (Example A92 to A101, Comparative Example A38 to A39, Reference Example A9)

Evaluation of the 6F22 batteries with anode zinc plate from

anode active material with additives of bismuth, indium, magnesium, or zirconium to zinc.

The result is shown in Table AA3 below.

[0078] Table AA3

	Cathode compound	Bismuth added amount	Added ingredient & amount	Corrosion decrease	Corrosion decrease unbiased variance value	Life relative value	Life relative value unbiased variance value
Example A92	C	0.01	-	8.6	0.812	101	1.31
Example A93	C	0.10	-	3.7	0.0152	100	0.07
Example A94	C	0.20	-	2.2	0.0111	100	0.0612
Example A95	C	0.30	-	2.1	0.00628	100	0.0752
Example A96	C	0.40	-	1.7	0.00270	100	0.102
Example A97	C	0.50	-	1.5	0.00691	100	0.0618
Example A98	C	0.70	-	1.2	0.00612	100	0.0813
Comparative example A38	C	-	-	12.8	1.21	98	2.68
Comparative example A39	C	-	In0.10	23.0	8.11	92	21.1
Reference example A9	C	-	Pb0.40	4.5	0.00191	100	0.0891
Example A99	C	0.30	Mg0.03	2.1	0.00278	100	0.0715
Example A100	C	0.30	Zr0.05	2.2	0.00678	101	0.0782
Example A101	C	0.30	Zr0.001	1.7	0.00612	100	0.0681

[0079]

As Table AA3 describes, the evaluation result revealed that the batteries made in embodying this invention has longer life than that of the batteries of the material without additive of bismuth (Comparative example A38) and the material with sole additive of indium (Comparative example A39) to zinc. And, the life of the batteries by this invention was not less than or equal to that of conventional batteries from the material with additive of lead to zinc.

[0080] (Example A102 to A112, Comparative Example A40 to A41, Reference Example A10)

Life test of batteries made of;

- anode zinc sheet from anode active materials with different additives indium, magnesium, and zirconium beside bismuth to zinc.

- Cathode compound with additives nickel 2.9ppm, cobalt 0.40ppm, and copper 0.86ppm to manganese dioxide.

Result in Table A'4.



[0081] Table AA4

	Cathode compound	Bismuth added amount	Added ingredient & amount	Corrosion decrease	Corrosion decrease unbiased variance value	Life relative value	Life relative value unbiased variance value
Comparative example A40	A	-	-	12.8	1.25	72	22.5
Example A102	A	0.01	-	9.1	0.812	94	31.9
Example A103	A	0.10	-	3.9	0.0156	100	0.716
Example A104	A	0.20	-	2.2	0.0121	100	0.148
Example A105	A	0.30	-	1.9	0.00612	101	0.785
Example A106	A	0.40	-	1.7	0.00287	100	0.491
Example A107	A	0.50	-	1.4	0.00691	101	0.812
Example A108	A	0.70	-	1.2	0.00611	101	0.161
Comparative example A41	A	-	In0.10	22.8	8.12	71	65.8
Reference example A10	A	-	Pb0.40	4.3	0.00198	100	0.281
Example A109	A	0.30	Mg0.03	2.5	0.00291	100	0.495
Example A110	A	0.30	Zr0.05	2.4	0.00666	100	2.35
Example A111	A	0.30	Sr0.005	2.6	0.0021	102	3.81
Example A112	A	0.30	Ba0.05	3.8	0.180	100	7.12

[0082]

As Table AA4 depicts, the batteries by this invention have not less life than that of the lead-contained battery (Reference example A10) and have longer life than that of the batteries of Comparative examples.

[0083] (Example A113 to A119, Comparative Example A42 to A45, Reference Example A11)

Life test of batteries made of;

• anode cans from anode active materials with different additives magnesium, zirconium, strontium, or barium, beside bismuth, to zinc.

• Cathode compound with additives nickel 2.9ppm, cobalt 0.40ppm, and copper 0.86ppm to manganese dioxide.

Result in Table AA5.

[0084] Table AA5

	Cathode compound	Bismuth added amount	Added ingredient & amount	Corrosion decrease	Corrosion decrease unbiased variance value	Life relative value	Life relative value unbiased variance value
Comparative example A42	B	0.01	-	10.1	0.0801	74	61.2
Comparative example A43	B	0.10	-	3.8	0.0161	100	3.15
Example A113	B	0.20	-	2.6	0.0131	101	2.20
Example A114	B	0.30	-	2.2	0.00581	100	0.980
Example A115	B	0.40	-	1.8	0.00282	100	1.30
Example A116	B	0.50	-	1.5	0.00691	100	0.81
Example A117	B	0.70	-	1.3	0.00712	101	0.55
Reference example A11	B	-	Pb0.40	4.8	0.00192	100	4.21
Example A118	B	0.30	Mg0.03	3.0	0.00311	101	2.05
Example A119	B	0.20	Zr0.05	3.2	0.00911	100	2.99
Comparative example A44	B	0.30	Sr0.05	3.4	0.00283	97	5.12
Comparative example A45	B	0.20	Ba0.05	4.2	0.415	81	58.4

[0085]

As Table AA5 depicts, the batteries by this invention have not less life than that of the lead-contained battery (Reference example A11) and have longer life than hat of the batteries of Comparative examples.

[0086] (Example B)

Following is a detailed description of an Example of this invention.

Obtained was a battery anode zinc material from a lot of purity 99.99 percent by mass zinc ground metal which contained

inevitable impurities, adding a specified amount of bismuth but none of lead. Zinc ground metal naturally and inevitably contains accompaniment impurities such as copper, iron, cadmium and lead on the ppm order. Zinc pellets of specified dimensions were made out of a zinc sheet which was processed from the zinc material ingot by hot rolling. From the pellets, zinc electrodes 0.35 mm thick with the bottom cover were fabricated by press forming the sheet to the equilateral hexagon zinc plate 31 mm diagonal length and 6 mm thickness; loading pressure 100t, heat to the pellet  $150 \pm 30$  degrees Centigrade. At this time Yokogawa Digital Heat Emission Thermometer 530 04, its laser pointer, was used to measure the temperature of the pellet surface in punching process. After deep-drawing checked was if finish of the cans O.K. or N.G and if any or no crack or dent. Further metal structure of the cans was inspected for cracks and metal condition.

Subsequently, R20 manganese dry batteries were manufactured with the fabricated zinc electrodes, followed by corrosion test of the anode zinc material, measuring crystal grain diameter, and evaluation of the battery characteristics.

[0087] (Measuring Method of Average Crystal Grain Diameter)

Following explains measuring method of average crystal grain diameter. Test samples were cut of the zinc electrodes at 15 mm below from the top-end, the can's opening, to look at the crystal structure of that region, and the zinc crystals composing the cross section of the region were measured for grain diameter.

Degreasing the sample with 10% NaOH solution and acetone, fixing it upright to expose the cut section with epoxy adhesive (trade brand: Araldite), and polishing the surface, the section was magnified 100 times by a polarizing microscope and was photographed by a digital still camera.

Measuring was done in such a way; count grain diameter of the crystals along a horizontal line on the image photographed; compute out the average crystal grain diameter in the region using Nikon's Stage Micrometer. The number of the test sample was 5. Average grain diameter was obtained from the line on 10 regions per each of 5 samples. To get variance, Standard Error of Mean was calculated out of 5 data of measurement result (average grain diameter) from each of 5 samples. The value was used for the index of variance.

[0088] (Corrosion resistant test of the anode zinc can)

Following explains about corrosion resistant test of the material for the anode zinc can.

Cutting test samples (a piece 1.3 mm thick 1.0 mm width, 50.0 mm length) out of the zinc electrodes, the samples were polished at their surface and cross section to mirror face status with the sand papers #400, #600, #800, #1000 and #1200, and were degreased in an Ultrasonic Wave Cleaner. The liquid used was of 10 percent by mass of NaOH and acetone. The degreased sample was weighed in 0.1 mg accuracy and then dipped into electrolyte in a constant temperature water chamber. Weight decrease of the

sample after 66 hours in 45degrees Centigrade was taken for decrease by corrosion or corrosion-decrease.

The electrolyte used for the test was made from zinc chloride 25 percent by mass and ammonium chloride 2 percent by mass, that is, a normal electrolyte composition. To it added was an amount of the standard solution of Ni, Co, and Cu for atomic absorbency method to adjust concentration of the electrolyte to be Ni 2.9ppm, Co 0.40ppm, and Cu 0.86ppm. The electrolyte was bubbled for 10 minutes by argon gas to deter affect of unsolved oxygen. That completed the electrolyte. Six samples were tested to get average corrosion-decrease.

[0089] (3) Evaluation of battery characteristics

Three types of cathode compound were prepared mixing well those substances to be homogeneous; 50 parts by mass of purity 92% above electrolytic manganese dioxide (impurity: copper below 0.0005 percent by mass, iron below 0.02 percent by mass, lead below 0.0005 percent by mass). 9 parts by mass of acetylene black containing ash 0.01 percent by mass, and 50 parts by mass of zinc dioxide adding 49 parts by mass of the electrolyte referred in 0084 above. The electrolyte is a mixture of zinc chloride 25 percent by mass and ammonium chloride 2 percent by mass. The amount of impurities in the prepared cathode compound is equivalent to that low grade natural manganese dioxide elutes to electrolyte in a normal temperature during 1 year after being manufactured.

[0090]

The separator prepared is a piece of craft paper coated with chemical starch of, cross linkage ether of cornstarch.

Using the abovementioned anode zinc materials, made out were R20 manganese dry batteries. The attached drawing 1 describes this type of battery. 1 refers to the anode zinc can, 2 the separator, 3 the cathode compound, 4 the carbon rod for collecting current, 5 the gasket, 6 the positive terminal, 7 the negative terminal, 8 the insulating tube, and 9 the outer can cover.

Asphalt seal material was coated the contact faces of the carbon rod 4 and the seal to shut out oxygen to enter through a gap between the press inserted carbon rod 4 and the gasket 5.

After storing the battery in a constant temperature chamber of 20degrees Centigrade  $\pm$  2degrees Centigrade for 10 days and further storing in a constant temperature chamber in 40degrees Centigrade for 30days, the batteries were discharged with a load of 40 ohm ( $\Omega$ ) for 4 hours a day in a room temperature. Subsequently evaluated was life characteristic at the time of 1.1 V, and obtained was relative values to 100 the standard representing the characteristic of conventional and currently available batteries. The number of the samples was 9 of R20 made in this work.

[0091] (Example B1 to B8, Comparative Example B1 to B2, and Reference Example B1 & B2)

With 20 samples of the battery, checked was crack, and

measured were crystal grain diameter, corrosion decrease of the anode zinc material containing specified amount of bismuth added, and battery life by discharge under specified conditions. The results are shown in Table B1 herein below.

[0092]

Likewise, for comparison check and measurement were conducted for the batteries of zinc electrodes formed in different temperature from the range of this invention and from the anode material without adding bismuth as to crack, grain diameter, corrosion decrease, and battery life.

Table B1 describes those results.

[0093]

For comparative reference, foregoing test was done on a battery of a zinc can from the material with lead 0.02 percent by mass added as conventionally and currently done (Reference example B1), and another battery of a can from the material without adding lead but adding indium 0.01 percent by mass (Example B2).



[0094] Table B1

	Bismuth amount (Mg amount)	Average grain diameter	Standard error	Corrosion decrease	Material temperature in processing can	Number of crack	Life relative value
Reference example B1	Pb0.2	30.3	1.17	4.8	180	0	100
Reference example B2	In0.01	26.7	1.23	21.0	210	3	66
Example B1	0.1	20.6	0.92	3.8	162	0	101
Example B2	0.3	12.7	0.049	2.0	211	0	101
Example B3	0.3	12.7	0.049	2.0	230	1	101
Example B4	0.5	10.8	0.033	1.3	203	0	101
Example B5	0.7	7.8	0.023	1.1	182	0	102
Example B6	0.8	7.7	0.033	1.1	118	0	101
Example B7	0.3 (Mg0.0003)	12.9	0.067	2.0	158	0	100
Example B8	0.3 (Mg0.002)	12.6	0.071	2.1	155	0	100
Example B9	0.3 (Mg0.003)	12.4	0.072	2.0	154	0	101
Comparative example B1	0.3 (Mg0.004)	-	-	-	155	17	-
Comparative example B2	-	48.2	1.33	12.0	155	0	69

[0095]

The result shows corrosion decrease of less than or equal to 3.9 mg for every Example, as compared to 12.0 mg of the examples of grain diameter out of the range of this invention. It is obvious that corrosion resistance was substantially improved in the Examples, which also evidences very few cracks endorsing superior process-ability. And life of the batteries by this invention was not less than or equal to that of conventional batteries from lead-added zinc material.

[0096] (Example B')

[0097]

Following is detailed description of an Example. Obtained was a battery anode zinc material from a lot of zinc ground metal purity 99.99% without adding lead and adding specified amount of bismuth. The zinc ground metal inevitably contained impurities such as copper, iron, and cadmium on the ppm order. Hot rolling the zinc ingot to a sheet, and rolling further the sheet to 0.5 mm thick, coating conductive paint, drying up, and then the sheet was punched out to required shape. At this juncture, Yokogawa Digital Heat Emission Thermometer 530 04, its laser pointer. was used to measure the temperature of the sheet surface in rolling process. After process the zinc sheet was checked in surface condition, dent, and crack using a microscope. Further, metal structure of the sheet was looked into for cracks and metal condition. Subsequently 6F22 quadrilateral laminated manganese dry batteries were made using the processed zinc plates, followed by corrosion test of the zinc plates, measurement of crystal grain diameter, and characteristic evaluation of the battery.

[0098] (Measuring Method of Average Crystal Grain Diameter)

Following explains measuring method of average crystal grain diameter. Test samples were cut out of the zinc plates horizontally to a flat face for looking at the crystal structure at cross section, and grain diameter of the zinc crystals composing the cross-section were measured. Degreasing the sample with 10% NaOH solution and acetone, fixing it upright to expose the cut section with epoxy adhesive (trade brand: Araldite), and polishing

the surface, the section was magnified 100 times by a polarizing microscope and was photographed by a digital still camera. Measuring was done in such a way; measuring grain diameter of the crystals along a horizontal line on the image photographed; computing out the average crystal grain diameter in the region using Nikon's Stage Micrometer. The number of the test sample was 5. Average grain diameter was obtained from a line on 10 regions per each of 5 samples. To get variance, Standard Error of Mean was calculated out of 5 data of measurement (average grain diameter) from each of 5 samples. The value was used for the index of variance.

[0099] (Corrosion resistant test of the anode zinc sheet)

Following explains about corrosion resistant test of the material for the anode zinc sheet.

Cutting out test samples (a piece 0.5 mm thick 10.0 mm width, 50.0 mm length) of the zinc plates horizontally to the flat face, the samples were polished at their surface and cross section to mirror face status with the sand papers #400, #600, #800, #1000 and #1200, and were degreased in an ultrasonic wave cleaner. The liquid used were 10 percent by mass of NaOH and acetone. The degreased sample was weighed in 0.1 mg accuracy and then dipped into electrolyte in a constant temperature water chamber prepared. Weight decrease of the sample after 66 hours in 45degrees Centigrade was taken for corrosion-decrease.

The electrolyte used for the test was made from zinc chloride

25 percent by mass and ammonium chloride 2 percent by mass, that is, a normal electrolyte composition. To it added was an amount of the standard solution of Ni, Co, and Cu for atomic absorbency method to adjust concentration of the electrolyte to be Ni 2.9ppm, Co 0.40ppm, and Cu 0.86ppm. The electrolyte was bubbled for 10 minutes by argon gas to deter affect of unsolved oxygen. Six samples were tested to get average corrosion-decrease.

### [0100] (3) Evaluation of battery characteristics

Three types of cathode compound were prepared mixing well those substances to be homogeneous: 50 parts by mass of purity 92% above electrolytic manganese dioxide (impurity: copper below 0.0005 percent by mass, iron below 0.02 percent by mass, lead below 0.0005percent by mass), 9 parts by mass of acetylene black containing ash below 0.01 percent by mass, and 26 percent by mass of zinc dioxide adding 49 parts by mass of the electrolyte referred in 0084 above. The electrolyte is a mixture of zinc chloride 25 percent by mass and ammonium chloride 2 percent by mass, and the amount of impurities in the prepared cathode compound is equivalent to that low grade natural manganese dioxide elutes to electrolyte in a normal temperature during 1 year after being manufactured.

### [0101]

The separator prepared is a piece of craft paper coated with chemical starch of cross linkage ether of cornstarch.

Using the abovementioned anode zinc materials, made out were 6F22, manganese dry batteries. The attached drawing 2 describes this type of battery.

After storing the battery thus made in a constant temperature chamber of 20degrees Centigrade  $\pm$  2degrees Centigrade for 10 days and further storing in a constant temperature chamber in 40degrees Centigrade for 30days, the battery was discharged with a load of 620 ohm( $\Omega$ ) for 2 hours a day in a room temperature. Subsequently evaluated was life characteristic at the time of 6.6V, and obtained was relative values to 100 the standard caliber.

The number of the samples for evaluation was 9 pieces of 6F22 battery.

[0102] (Example B9 to B16, Comparative Example B3 to B4, Reference Example B3 & B4)

With 20 samples of the battery, checked and measured were crack, crystal grain diameter, corrosion decrease of the anode zinc material containing specified amount of bismuth added, and battery life by discharge under specified conditions. The results are shown in Table B'1 herein below.

[0103]

Likewise, for comparison measurement was conducted for the batteries of thin zinc sheets rolled in a different temperature from the range of this invention and from the anode material without

adding bismuth in respect of crack, grain diameter, corrosion-decrease, and battery life.

Table BB1 describes those results.

Also for comparative reference, foregoing test was done on a battery of a zinc sheet from the material with lead 0.02 percent by mass added as conventionally and currently done (Reference example B3), and another battery of a sheet from the material without adding lead but adding indium 0.01 percent by mass (Example B4).

[0104] Table BB1

	Bismuth amount (Mg amount)	Average grain diameter	Standard error	Corrosion decrease	Material temperature in rolling	Number of crack	Life relative value
Reference example B3	Pb0.2	30.1	1.20	4.9	181	0	100
Reference example B4	In0.01	25.7	1.31	21.2	212	7	71
Example B10	0.1	20.1	1.00	3.9	171	0	100
Example B11	0.3	12.8	0.051	2.2	213	0	101
Example B12	0.5	11.2	0.033	1.4	212	0	100
Example B13	0.7	8.1	0.021	1.2	190	0	101
Example B14	0.8	7.9	0.041	1.3	119	0	101
Example B15	0.3 (Mg0.0003)	12.8	0.061	2.1	181	0	100
Example B16	0.3 (Mg0.003)	12.7	0.078	2.5	167	0	100
Example B17	0.3 (Mg0.03)	12.5	0.073	2.2	168	0	101
Comparative example B3	0.3 (Mg0.04)	-	-	-	169	9	-
Comparative example B4	-	49.1	1.41	13.5	160	0	75

[0105]

The result shows corrosion-decrease less than or equal to 3.9 mg for every example, as compared to 13.5 mg of the examples of grain diameter out of the range of this invention. It is obvious

that corrosion resistance was substantially improved in the Examples, which also evidences very few cracks endorsing superior process-ability. And life of the batteries by this invention was not less than or equal to that of conventional batteries from lead-added zinc material.

[0106] (Example C1 to C4, Comparative Example C1)

Made was a bar of ingot 200mm wide, 10 mm thick, 750 mm long from a lot of 99.5 percent by mass pure zinc containing impurities: lead below 70ppm after casting and cooling down, cadmium below 20ppm, iron below 30ppm, copper 10ppm, and antimony below 1ppm, adding bismuth by the amount shown in Table C1 below, melting together in  $470 \pm 50$  degrees Centigrade, and cooling down to a room atmospheric temperature. Rolling the cast bar, after cooling, in the surface temperature  $150 \pm 30$  degrees Centigrade to a sheet  $4.5 \pm 0.2$  mm. Subsequently the sheet was punched to hexagonal pellets. The pellets were placed onto a die with a round hole, press inserted a cylindrical punch sharply, and were deep-drawn by impact to form cylindrical cans. The cans were trimmed to outer diameter  $31.4 \pm 0.1$  mm, bottom thickness  $0.42 \pm 0.4$  mm, and total height  $54.1 \pm 0.2$  mm, the dimensions of a manganese dry battery.

[0107]

Using the anode cans, the cathode compound, and separators, two of which are explained herein below, manufactured were R20

manganese dry batteries.

- The cathode compound:
  - 53 parts by mass of manganese dioxide, purity above 78 percent by mass (impurity: Fe below 5.0%, Cu below 0.06%, nickel below 0.08%, cobalt below 0.05%, and arsenic below 0.01%)
  - 8 parts by mass of acetylene black containing ash below 0.1 percent by mass
  - 39 parts by mass of electrolyte containing 26 percent by mass zinc chloride plus 1.5 percent by mass ammonium chloride

All mixed and churned wet, and homogeneous compound was prepared.

- The separator

The separator prepared is a piece of craft paper coated with chemical starch of cross linkage ether of cornstarch.

[0108] Table C1

	Bi Mass concentration (percent by mass)	Average grain diameter ( $\mu$ m)	Standard error of Mean (S.E.M)	O/I ratio	Corrosion decrease (mg)	Material hardness (HV)
Example C1	0.08	24.8	0.95	1.40	4.0	40
Example C2	0.1	21.1	0.92	1.41	3.8	40
Example C3	0.3	12.7	0.049	1.15	2.0	41
Example C4	0.7	7.8	0.023	1.04	1.1	41
Comparative example C1	0.05	40.3	1.15	1.67	5.8	32



## [0109] (Comparative Example C2 &amp; C3)

Also fabricated were manganese batteries adding lead to anode material by the specified amount (Pb) in Table C2, without adding any bismuth, otherwise under the same conditions as for Examples in Table C1 above.

[0110] Table C2

	Pb Mass concentration (percent by mass)	Average grain diameter ( $\mu$ m)	Standard error of Mean (S.E.M)	O/I ratio	Corrosion decrease (mg)	Material hardness (HV)
Comparative example C2	0.2	30.3	1.17	1.52	4.8	44
Comparative example C3	0.4	14.8	1.58	1.46	4.2	45

## [0111] (Example C5 &amp; C6, Comparative Example C4)

Also fabricated were manganese dry batteries adding 0.3 percent by mass bismuth and magnesium by the specified amount in Table C3 to anode material, otherwise under the same conditions as for Examples stated above. And also, as comparative example C4, fabricated were manganese dry batteries adding 0.3 percent by mass bismuth and 0.005 percent by mass magnesium to anode material.

[0112] Table C3

	Mg Mass concentration (percent by mass)	Average grain diameter ( $\mu$ m)	Standard error of Mean (S.E.M)	O/I ratio	Corrosion decrease (mg)	Material hardness (HV)
Example C5	0.0003	12.9	0.067	1.18	2.0	44

Example C6	0.003	12.4	0.072	1.21	2.1	47
Comparative example C4	0.005	Material friable, no useable sample obtained.				

[0113] (Measuring Method of Average Crystal Grain Diameter)

Following explains measuring method of average crystal grain diameter. Test samples were cut out of the zinc electrodes at 15 mm below from the top-end, the can's opening edge to look at the crystal structure of the region, and the zinc crystals composing the cross-section of the region were measured in grain diameter.

Degreasing the sample with 10% NaOH solution and acetone, fixing it upright to expose the cut section with epoxy adhesive (trade brand: Araldite), and polishing the surface, the section was magnified 100 times by a polarizing microscope and was photographed by a digital still camera. Measuring was done in such a way; counting grain diameter of the crystals along a horizontal line on the image photographed; computing out the average crystal grain diameter in the region using Nikon's Stage Micrometer. The number of the test sample was 5. Average grain diameter was obtained from the line on 10 regions per each of 5 samples.

[0114]

Measurement was conducted on the metal structure within a region  $200\ \mu\text{m}$  from the inner wall surface and from the outer wall surface. The ratio of two average grain diameter was computed out.

To get variance, Standard Error of Mean was calculated out of 5 data of measurement result (average grain diameter) from each of 5 samples. The value was used for the index of variance.

Those results are indicated in Table C1, C2, and C3.

[0115] (Corrosion resistant test of the anode zinc can)

Following explains about carbon resistant test of the material for the anode zinc can.

Cutting out test samples (a piece 1.3 mm thickness 1.0 mm width, 50.0 mm length) of the zinc electrodes, the samples were polished at their surface and cross section to mirror face status with the sand papers #400, #600, #800, #1000 and #1200, and were degreased in an Ultrasonic Wave Cleaner. The liquid used were 10 percent by mass of NaOH and acetone. The degreased sample was weighed in 0.1 mg accuracy and then dipped into electrolyte in a constant temperature water chamber. Weight decrease of the sample after 66 hours in 45degrees Centigrade was taken for corrosion decrease.

The electrolyte used for the test was made from zinc chloride 25 percent by mass and ammonium chloride 2 percent by mass, that is, a normal electrolyte composition. To it added was an amount of the standard solution of Ni, Co, and Cu for atomic absorbancy method to adjust concentration of the electrolyte to be Ni 2.9ppm, Co 0.40ppm, and Cu 0.86ppm. The electrolyte was bubbled for 10 minutes by argon gas to deter affect of unsolved oxygen. 6 samples were tested to get average corrosion decrease.

The results are located in Table C1, C2, and C3.

[0116] (Measuring hardness of anode cans)

Cutting 5 samples of 20 mm<sup>2</sup> piece out of the central area of the anode zinc electrodes, Vickers hardness of each sample was measured, and average value was calculated out.

The results can be seen in Table C1, C2, and C3.

[0117] (Leakage proof test)

Having placed R20 batteries still in a constant temperature chamber in  $20 \pm 2$  degrees Centigrade and humidity  $65 \pm 20\%$ , and event of leakage was checked by excess discharge for 60 days with  $20 \Omega \pm 5\%$  tolerance of metal coated carbon resistor widely available on the market.

The sample: 100 pieces of the battery

The result is shown in Table C4 below.

[0118] Table C4

	Bi Mass concentration (percent by mass)	Number of days discharged & leakage happening %		
		20d	40d	60d
Example C7	0.08	0	0	0
Example C8	0.1	0	0	0
Example C9	0.3	0	0	0
Example C10	0.7	0	0	0
Comparative example C5	0.05	0	6	14

[0119] (Comparative Example C6 & C7)

Also fabricated were manganese dry batteries adding lead to anode material by the specified amount (Pb) in Table C5, without adding any bismuth, otherwise under the same conditions as for Examples stated above.

[0120] Table C5

	Pb Mass concentration (percent by mass)	Number of days discharged & leakage happening %		
		20d	40d	60d
Comparative example C6	0.2	0	0	10
Comparative example C7	0.4	0	0	4

[0121] (Example C11 &amp; C12)

Also fabricated were manganese dry batteries adding 0.3 percent by mass bismuth and magnesium by the specified amount in Table C6 to anode material, otherwise under the same conditions as for the Examples stated above.

[0122] Table C6

	Mg Mass concentration (percent by mass)	Number of days discharged & leakage happening %		
		20d	40d	60d
Example C11	0.0003	0	0	0
Example C12	0.003	0	0	0

[0123] (Example C', Example C13 to C16, Comparative Example C8)

Made was a bar of ingot 200mm wide, 10 mm thick, 750 mm long from a lot of 99.5 percent by mass pure zinc containing impurities: lead below 70ppm after casting and cooling down, cadmium below 20ppm, iron below 30ppm, copper 10ppm, and antimony below 1ppm, adding bismuth amount shown in Table CC1 below, melting together in  $470 \pm 50$  degrees Centigrade, and cooling down to a room atmospheric temperature. Rolling the cast bar, after cooling, in

the surface temperature  $150 \pm 30$  degrees Centigrade to a sheet  $4.5 \pm 0.2$  mm. The sheet was further rolled in the surface temperature in 120 degrees Centigrade to 210 degrees Centigrade to a 0.5 mm zinc sheet. Subsequently the sheet was coated with conductive paint, dried up, and punched to a specified shape for an anode zinc plates of 6F22 battery.

[0124]

Using the zinc plate, cathode compound, and a separator, two of which explained herein below, manufactured were 6F22 manganese dry batteries.

- The cathode compound:

- 53 parts by mass manganese dioxide, purity above 78 percent by mass (impurity: Fe below 5.0%, Cu below 0.06%, nickel below 0.08%, cobalt below 0.05%, and arsenic below 0.01%)
- 8 parts by mass acetylene black containing ash below 0.1 percent by mass
- 39 parts by mass electrolyte containing 26 percent by mass zinc chloride plus 1.5 percent by mass ammonium chloride

All mixed and churned wet, and homogeneous compound was prepared.

- The separator

The separator prepared is a piece of craft paper coated with

chemical starch of cross linkage ether of cornstarch.

[0125] Table CC1

	Bi Mass concentration (percent by mass)	Average grain diameter ( $\mu$ m)	Standard error of Mean (S.E.M)	Corrosion decrease (mg)	Material hardness (HV)
Example C13	0.08	25.1	1.00	5.1	43
Example C14	0.1	21.3	0.98	3.3	45
Example C15	0.3	12.8	0.061	2.1	42
Example C16	0.7	8.1	0.031	1.0	43
Comparative example C8	0.05	45.6	1.28	6.1	35

[0126] (Comparative Example C9 C10)

Also fabricated were 6F22 manganese dry batteries adding lead to anode material by the specified amount (Pb) in Table CC2, without adding any bismuth, otherwise under the same conditions as for Examples stated above.

[0127] Table CC2

	Pb Mass concentration (percent by mass)	Average grain diameter ( $\mu$ m)	Standard error of Mean (S.E.M)	Corrosion decrease (mg)	Material hardness (HV)
Comparative example C9	0.2	30.5	1.21	5.1	41
Comparative example C10	0.4	16.2	1.61	4.3	43

[0128] (Example C17 & C18, Comparative Example C11)

Also fabricated were manganese dry batteries adding 0.3 percent by mass bismuth and magnesium by the specified amount in



Table C3 to anode material, otherwise under the same conditions as for Examples stated above. And also, as comparative example C4, fabricated were 6F22 manganese dry batteries adding 0.3 percent by mass bismuth and 0.005 percent by mass magnesium to anode material.

[0129] Table CC3

	Mg Mass concentration (percent by mass)	Average grain diameter ( $\mu$ m)	Standard error of Mean (S.E.M)	Corrosion decrease (mg)	Material hardness (HV)
Example C17	0.0003	13.1	0.071	2.1	42
Example C18	0.03	12.7	0.077	2.3	54
Comparative example C11	0.04	Material friable, no useable sample obtained.			

[0130] (Measurement of average grain diameter)

Following method of measuring was done as to average crystal grain diameter of anode plates for 6F22 manganese dry batteries in the Examples and the comparative examples.

[0131]

Test samples were cut out of the zinc plates horizontally to the flat face to look at the crystal structure of the region, and the zinc crystals composing the cross section of the region were measured for grain diameter.

Degreasing the sample with 10% NaOH solution and acetone, fixing it upright to expose the cut section with epoxy adhesive (trade brand: Araldite), and polishing the surface, the section

was magnified 100 times by a polarizing microscope and was photographed by a digital still camera. Measuring was done in such a way; counting grain diameter of the crystals along a horizontal line on the image photographed; computing out the average crystal grain diameter in the region using Nikon's Stage Micrometer. The number of the test sample was 5. Average grain diameter was obtained from 10 regions per each of 5 samples.

[0132] (Corrosion resistant test of the anode zinc plate)

Following explains about corrosion resistant test of the material for the anode zinc plates.

Cutting test samples (a piece 0.5 mm thick 1.0 mm width, 50.0 mm length) out of the zinc plates, the samples were polished at their surface and cross section to mirror face status with the sand papers #400, #600, #800, #1000 and #1200, and were degreased in an Ultrasonic Wave Cleaner. The liquid used were 10 percent by mass of NaOH and acetone. The degreased sample was weighed in 0.1 mg, accuracy and then dipped into electrolyte in a constant temperature water chamber. Weight decrease of the sample after 66 hours in 45degrees Centigrade was taken for corrosion decrease. The electrolyte used for the test was made from zinc chloride 25 percent by mass and ammonium chloride 2 percent by mass, that is, a normal electrolyte composition. To it added was an amount of the standard solution of Ni, Co, and Cu for atomic absorbancy method to adjust concentration of the electrolyte to be Ni 2.9ppm, Co 0.40ppm, and Cu 0.86ppm. The electrolyte was bubbled for 10 minutes

by argon gas to deter affect of unsolved oxygen. 6 samples were tested to get average corrosion decrease.

The results are shown in Table CC1, CC2, and CC3.

[0133] (Measuring hardness of anode plates)

Cutting 5 samples out of the anode zinc plates, Vickers hardness of each sample was measured, and average value was calculated out.

The results can be seen in Table CC1, CC2, and CC3.

[0134] (Leakage proof test)

Having placed fabricated 6F22 batteries still in a constant temperature chamber in  $20 \pm 2$ degrees Centigrade and humidity  $65 \pm 20\%$ , and event of leakage was checked by excess discharge for 60 days with  $620\Omega \pm 5\%$  tolerance metal coated carbon resistor widely available on the market.

The sample number: 100

The result is shown in Table CC4 below.

[0135] Table CC4

	Bi Mass concentration (percent mass) by	Number of days discharged & leakage happening %		
		20d	40d	60d
Example C19	0.08	0	0	0
Example C20	0.1	0	0	0
Example C21	0.3	0	0	0
Example C22	0.7	0	0	0
Comparative example C12	0.05	0	3	7

## [0136] (Comparative Example C13 &amp; C14)

Also fabricated were manganese dry batteries adding lead to anode material by the specified amount (Pb) in Table CC5, without adding any bismuth, otherwise under the same conditions as for Examples stated above.

[0137] Table CC5

	Pb Mass concentration (percent by mass)	Number of days discharged & leakage happening %		
		20d	40d	60d
Comparative example C13	0.2	0	0	5
Comparative example C14	0.4	0	0	1

## [0138] (Example C23 &amp; C24)

Also fabricated were manganese dry batteries adding 0.3 percent by mass bismuth and magnesium by the specified amount in Table CC6 to anode material, otherwise under the same conditions as for the Examples stated above.

[0139] Table CC6

	Mg Mass concentration (percent by mass)	Number of days discharged & leakage happening %		
		20d	40d	60d
Example C23	0.0003	0	0	0
Example C24	0.003	0	0	0

[0140] (Evaluation)

As foregoing Examples and comparative examples evidence, this invention realizes manufacturing battery anode zinc electrodes and plates and batteries thereby without using lead, in the same material hardness equivalent to that of alloy wherein lead is compounded, and with less material decrease due to corrosion as compared to conventionally made zinc electrodes and plates. It is a discovery of this invention that decrease from corrosion and material hardness can be improved by compounding bismuth and adding magnesium to zinc alloy.

[0141] (Advantage of this invention)

As described above, this invention facilitates to make and supply practical and highly reliable anode zinc material, parts, and battery containing far much less lead pollutant as compared to conventional and currently supplied batteries, while the materials keep enough process-ability in addition to optimum material hardness, and the batteries have better corrosion resistance and leakage proof property.

## Brief Description of the Drawings

[0142]

Fig.1 depicts a brief cross sectional view of a manganese dry battery.

Fig.2 depicts a brief cross sectional view of a quadrilateral laminated manganese dry battery.

[0143]

The digit 1 in Fig.1 refers to the anode zinc can, 2 the separator, 3 the cathode compound, 4 the carbon rod current collector, 5 the gasket, 6 the positive terminal, 7 the negative terminal, 8 the insulation tube, and 9 the outer can.

The digit 11 in Fig.2 refers to the terminal, 12 the positive terminal (+), 13 the negative terminal (-), 14 the upper insulation strip, 15 the leading strip, 16 the electrode (current draw out) terminal, 17 the cathode compound, 18 the separator, 19 the zinc plate, 20 the carbon film, 21 the outer can, 22 the heat-shrink tube, and 23 the lower insulation strip.